
Chapter 1

Overview of Biogas Technology

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THE U.S. biogas experience has demonstrated that biogas technology is not applicable for all farms. In many situations however, it can be a cost-effective and environmentally-friendly method for treating manure and liquid waste. Biogas production is best suited for farms that handle large amounts of manure as a liquid, slurry, or semi-solid with little or no bedding added. Biogas systems require a financial investment and a management responsibility. The system must be designed by an experienced designer, who is well versed with the common problems associated with biogas production. Additionally, the farm owner or operator must be committed to the digester's success.

This chapter provides an overview of biogas technology and opportunities to use this technology in livestock facilities across the U.S. First, a brief description of biogas technology is provided. Then the benefits of biogas technology are discussed. Finally, the experience and status of biogas technology development in the U.S. are described.

1-1. What are the Components of a Biogas System?

Biogas technology is a manure management tool that promotes the recovery and use of biogas as energy by adapting manure management practices to collect biogas. The biogas can be used as a fuel source to generate electricity for on-farm use or for sale to the electrical grid, or for heating or cooling needs. The biologically stabilized byproducts of anaerobic digestion can be used in a number of ways, depending on local needs and resources. Successful byproduct applications include use as a crop fertilizer, animal feed, bedding, and as aquaculture supplements.

A typical biogas system consists of the following components:

- Manure Collection;
- Anaerobic Digester;
- Effluent Storage;
- Gas Handling; and
- Gas Use.

Each of these components is discussed briefly.

1-1.1 Manure Collection

Livestock facilities use manure management systems to collect and store manure because of sanitary, environmental, and farm operational considerations. Manure is collected and stored as either liquids, slurries, semi-solids, or solids.

- **Raw Manure.** Manure is deposited with a solids content of 8 to 25 percent, depending upon animal type. It can be diluted by various process waters or thickened by air drying or by adding bedding materials.
- **Liquid Manure.** Manure handled as a liquid has been diluted to a solids content of less than 3 percent. This manure is typically “flushed” from where it is deposited, often using fresh or recycled water. The manure and flush water can be pumped to treatment and storage tanks, ponds, lagoons or other suitable structures before land application. Liquid manure systems may be adapted for biogas production and energy recovery in “warm” climates. In colder climates, biogas recovery can be used, but is usually limited to gas flaring for odor control.
- **Slurry Manure.** Manure handled as a slurry has been diluted to a solids content of about 3 to 10 percent. Slurry manure is usually collected by a mechanical “scraper” system. This manure can be pumped, and is often treated or stored in tanks, ponds or lagoons prior to land application. Some amount of water is

generally mixed with the manure to create a slurry. For example, spilled drinking water mixes with pig manure to create a slurry. Manure managed in this manner may be used for biogas recovery and energy production, depending on climate and dilution factors.

- **Semi-Solid Manure.** Manure handled as a semi-solid has a solids content of 10 to 20 percent. This manure is typically scraped. Water is not added to the manure, and the manure is typically stored until it is spread on local fields. Fresh scraped manure (<1 week old) can be used for biogas and energy production in all climates, because it can be heated to promote bacterial growth.
- **Solid Manure.** Manure with a solids content of greater than 20% is handled as a solid by a scoop loader. Aged solid manure or manure that is left “unmanaged” (i.e., is left in the pasture where it is deposited by the animals) or allowed to dry is not suitable for biogas recovery.

1-1.2 Digester Types

The digester is the component of the manure management system that optimizes naturally occurring anaerobic bacteria to decompose and treat the manure while producing biogas. Digesters are covered with an air-tight impermeable cover to trap the biogas for on-farm energy use. The choice of which digester to use is driven by the existing (or planned) manure handling system at the facility. The digester must be designed to operate as part of the facility’s operations. One of three basic options will generally be suitable for most conditions. Exhibit 1-1 summarizes the main characteristics of these digester technologies:

- **Covered Lagoon.** Covered lagoons are used to treat and produce biogas from liquid manure with less than 2 percent solids. Generally, large lagoon volumes are required, preferably with depths greater than 12 feet. The typical volume of the required lagoon can be roughly estimated by multiplying the daily manure flush volume by 40 to 60 days. Covered lagoons for energy recovery are compatible with flush manure systems in warm climates. Covered lagoons may be used in cold

Exhibit 1-1 Summary Characteristics of Digester Technologies

Characteristics	Covered Lagoon	Complete Mix Digester	Plug Flow Digester
Digestion Vessel	Deep Lagoon	Round/Square In/Above-Ground Tank	Rectangular In-Ground Tank
Level of Technology	Low	Medium	Low
Supplemental Heat	No	Yes	Yes
Total Solids	0.5 - 3%	3 - 10%	11 - 13%
Solids Characteristics	Fine	Coarse	Coarse
HRT ^r (days)	40 - 60	15+	15+
Farm Type	Dairy, Hog	Dairy, Hog	Dairy Only
Optimum Location	Temperate and Warm Climates	All Climates	All Climates

^r Hydraulic Retention Time (HRT) is the average number of days a volume of manure remains in the digester.

climates for seasonal biogas recovery and odor control (gas flaring). Exhibit 1-2 illustrates a floating cover module for lagoon applications. Typically, multiple modules cover the lagoon surface and can be fabricated from various materials. Appendix F contains the NRCS Interim Practice Standard (360) for covered lagoons.

- **Complete Mix Digester.** Complete mix digesters are engineered tanks, above or below ground, that treat slurry manure with a solids concentration in the range of 3 to 10 percent. These structures require less land than lagoons and are heated. Complete mix digesters are compatible with combinations of scraped and flushed manure. Appendix F contains the NRCS Interim Practice Standard for complete mix digesters.
- **Plug Flow Digester:** Plug flow digesters are engineered, heated, rectangular tanks that treat scraped *dairy* manure with a range of 11 to 13 percent total solids. Swine manure

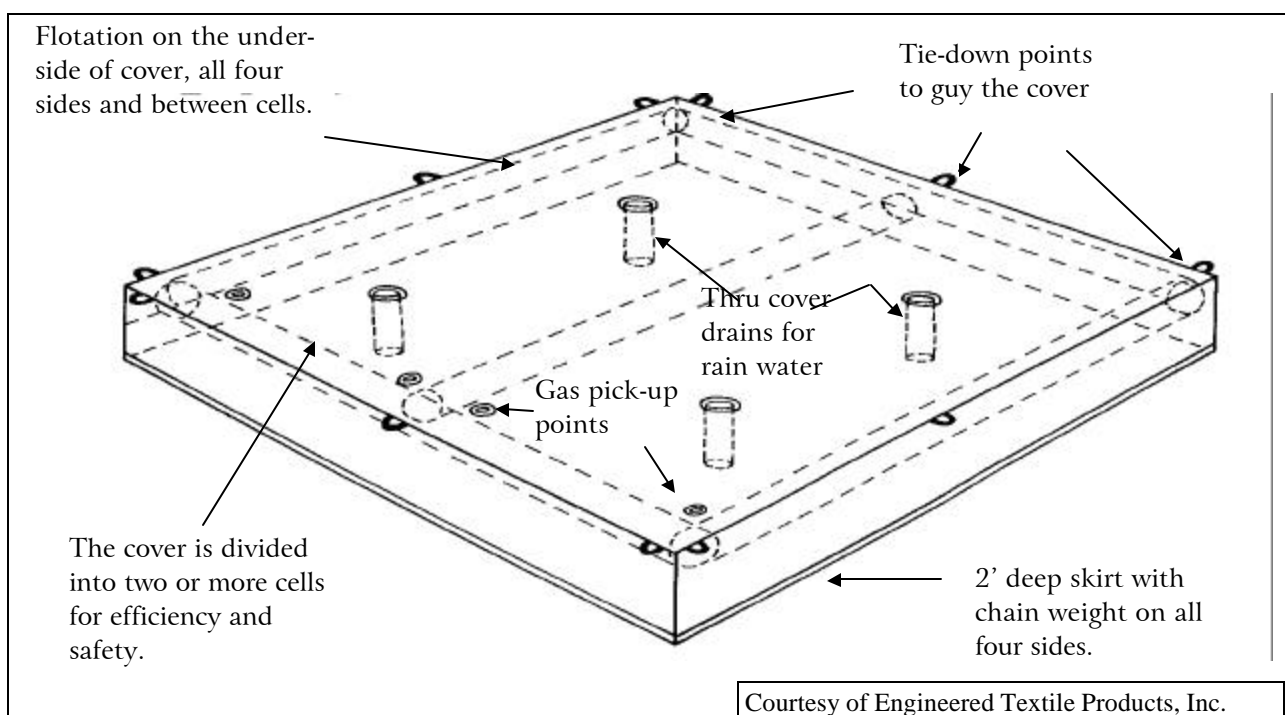
cannot be treated with a plug flow digester due to its lack of fiber. Appendix F contains the NRCS Interim Practice Standard for plug flow digesters.

1-1.3 Effluent Storage

The products of the anaerobic digestion of manure in digesters are biogas and effluent. The effluent is a stabilized organic solution that has value as a fertilizer, and other potential uses. Waste storage facilities are required to store treated effluent because the nutrients in the effluent cannot be applied to land and crops year round.

The size of the storage facility and storage period must be adequate to meet farm requirements during the non-growing season. Facilities with longer storage periods allow flexibility in managing the waste to accommodate weather changes, equipment availability and breakdown, and overall operation management.

Exhibit 1-2 Floating Cover Module for Lagoon Application



1-1.4 Gas Handling

A gas handling system removes biogas from the digester and transports it to the end-use, such as an engine or boiler.

Gas handling includes: piping; gas pump or blower; gas meter; pressure regulator; and condensate drain(s).

Biogas produced in the digester is trapped under an air-tight cover placed over the digester. The biogas is removed by pulling a slight vacuum on the collection pipe (e.g., by connecting a gas pump/blower to the end of the pipe) which draws the collected gas from under the cover. A gas meter is used to monitor the gas flow rate. Sometimes a gas scrubber is needed to clean or “scrub” the biogas of corrosive compounds contained in the biogas (e.g., hydrogen sulfide). Since the gas storage space is limited (i.e., the volume under the cover), a pressure regulator is used to release excess gas pressure from the cover. Warm biogas cools as it travels through the piping and water vapor in the gas condenses. A condensate drain(s) removes the condensate produced.

1-1.5 Gas Use

Recovered biogas can be utilized in a variety of ways. The recovered gas is 60-80 percent methane, with a heating value of approximately 600 - 800 Btu/ft³. Gas of this quality can be used to generate electricity; it may be used as fuel for a boiler, space heater, or refrigeration equipment; or it may be directly combusted as a cooking and lighting fuel. Most equipment that uses natural gas, propane, or butane as fuel can be fueled by biogas. Chapter 3 provides more information on biogas use.

Electricity can be generated for on-farm use or for sale to the local electric power grid. The most common technology for generating electricity is an internal combustion engine with a generator. The predicted gas flow rate and the operating plan are used to size the electricity generation equipment.

Engine-generator sets are available in many sizes. Some brands have a long history of reliable operation when fueled by biogas. Electricity generated in this manner can replace energy purchased from the local utility, or can be sold directly to the local electricity supply system. In addition, waste heat from these engines can provide heating or hot water for farm use.

Biogas can also be used directly on-site as a fuel for facility operations. Equipment that normally uses propane or natural gas can be modified to use biogas. Such equipment includes boilers, heaters, and chillers.

- **Boilers and Space Heaters.** Boilers and space heaters fired with biogas produce heat for use in the facility operations. Although this may not be the most efficient use of the gas, in some situations it may be a farm’s best option.
- **Chilling/Refrigeration.** Dairy farms use considerable amounts of energy for refrigeration. Approximately 15 to 30% of a dairy’s electricity load is used to cool milk. Gas-fired chillers are commercially available and can be used for this purpose. For some dairies, this may be the most cost effective option for biogas utilization.

Other energy use options may exist. For example, a nearby greenhouse could be heated with the biogas, and carbon dioxide from the heater exhaust could be used to enhance plant growth. These options need to be evaluated on a case-by-case basis.

1-2. Benefits of Biogas Technology

Most confined livestock operations handle manure as liquids, slurries, semi-solids, or solids that are stored in lagoons, concrete basins, tanks, and other containment structures. These structures are typically designed to comply with local and state environmental regulations and are a necessary cost of production.

Biogas technology can be a cost-effective, environment and neighborhood friendly addition to existing manure management strategies. Biogas technologies anaerobically digest manure, resulting in biogas and a liquefied, low-odor effluent. By managing the anaerobic digestion of manure, biogas technologies significantly reduce Biochemical Oxygen Demand (BOD), and pathogen levels; remove most noxious odors; and convert most of the organic nitrogen to inorganic N (e.g., ammonium).

The principal reasons a farmer or producer would consider installing a biogas system are:

- **On-Site Farm Energy.** By recovering biogas and producing on-farm energy, livestock producers can reduce monthly energy purchases from electric and gas suppliers.
- **Reduced Odors.** Biogas systems reduce offensive odors from overloaded or improperly managed manure storage facilities. These odors impair air quality and may be a nuisance to nearby communities. Biogas systems reduce these offensive odors because the volatile organic acids, the odor causing compounds, are consumed by biogas producing bacteria.
- **High Quality Fertilizer.** In the process of anaerobic digestion, the organic nitrogen in the manure is largely converted to ammonium, the primary constituent of commercial

fertilizer, which is readily available and utilized by plants.

- **Reduced Surface and Groundwater Contamination.** Digester effluent is a more uniform and predictable product than untreated manure. The higher ammonium content allows better crop utilization and the physical properties allow easier land application. Properly applied, digester effluent reduces the likelihood of surface or groundwater pollution.
- **Pathogen Reduction.** Heated digesters reduce pathogen populations dramatically in a few days. Lagoon digesters isolate pathogens and allow pathogen kill and die-off prior to entering storage for land application.

Biogas recovery can improve profitability while improving environmental quality. Maximizing farm resources in such a manner may prove essential to remain competitive and environmentally sustainable in today's livestock industry. In addition, more widespread use of biogas technology will create jobs related to the design, operation, and manufacture of energy recovery systems and lead to the advancement of U.S. agribusiness.

1-3. The U.S. Biogas Experience

Rising oil prices in the 1970's triggered an interest in developing "commercial farm-scale" biogas systems in the United States.

During this developmental period approximately 140 biogas systems were installed in the U.S., of which about 71 were installed at commercial swine, dairy, and caged layer farms. Exhibit 1-3 summarizes the status and technical classification for those farm-based systems. This table does not include the 70 digesters that were installed as university research and demonstration projects.

This is a key distinction because to understand the commercial status of U.S. biogas development it is important to look at the commercial farms that operate biogas systems. Appendix A lists some of these farms and provides some information about their biogas systems.

As indicated in Exhibit 1-3, many biogas systems failed. These failures have contributed to the current poor technical perception held by the livestock industry, and have resulted in very limited biogas development since.

However, learning from failures is part of the technology development process. Examining past failures led to improvements and refinements in existing technologies and newer, more practical systems. For example, the success rate of biogas systems built after 1982 was far greater than that of digesters built before 1982.

The main reasons for the success and failure of biogas recovery projects follow.

1-3.1 Reasons for Success

Biogas recovery projects succeeded because:

- 1. The owner/operator realized the benefits biogas technology had to offer and wanted to make it work.

- 2. The owner/operator had some mechanical knowledge and ability and had access to technical support.
- 3. The designer/builder built systems that were compatible with farm operation.
- 4. The owner/operator increased the profitability of biogas systems through the utilization and sale of manure byproducts. One facility operator generates more revenues from the sale of electricity and other manure byproducts than from the sale of milk.

1-3.2 Reasons for Failure

Biogas recovery projects failed because:

- 1. Operators did not have the skills or the time required to keep a marginal system operating.
- 2. Producers selected digester systems that were not compatible with their manure handling methods or layout of their farms.
- 3. Some designer/builders sold “cookie cutter” designs to farms. For example, of the 30 plug flow digesters built, 19 were built by one designer and 90% failed.
- 4. The designer/builders installed the wrong type of equipment, such as incorrectly sized engine-generators, gas transmission equipment, and electrical relays.

Exhibit 1-3 Status and Distribution of Commercial Farm Based Biogas Systems in the U.S.

	Complete Mix Digester	Plug Flow Digester	Covered Lagoon	TOTAL
Operating	9	9	7	25
Not Operating	13	30	3	46
TOTAL	22	39	10	71
Source: DOE, 1995 “Methane Recovery from Animal Manures: A Current Opportunities Casebook,” August 1995.				

5. The systems became too expensive to maintain and repair because of poor system design.
6. Farmers did not receive adequate training and technical support for their systems.
7. There were no financial returns of the system or returns diminished over time.
8. Farms went out of business due to non-digester factors.

This handbook draws from these lessons and provides a realistic screening process for livestock facilities to decide if biogas technology is an appropriate match for the farm and farm owner.